Low-Speed Mini-Motor Failure Recognition Using Fuzzy Theory

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Abstract

This paper proposal a method of fault diagnosis for low-speed mini-motor with acoustics signals under the motor is not disassembling condition. Due to there are two uncertain events between fault of motor and acoustics signals of motor. These events will be described by fuzzy logic. A new probability concept of fuzzy events will apply in the method. The condition of mini-motor running will be described by membership grade set of feature value of acoustics signals. By using the inference method a new membership set will result. The new membership set not only can judges the motor quality, but also can recognize the kind of motor failure. The high frequency spectrum energy of acoustics signals and low frequency spectrum energy of acoustics signal is applied in the method as optimal feature value. Actual experiment results and numerical simulation's results all show the method of the combination fuzzy theory is very effectively method for fault diagnosis of low-speed mini-motor.

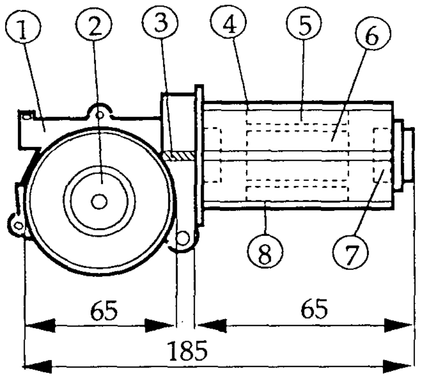
Key Words : diagnosis : low-speed mini-motor : acoustics signal : frequency spectrum : fuzzy the^ry.

1. Introduction

The manufacturing industry is surrounded with grave situation increasing year by year. Automation on manufacturing line is propulsion with factory automation. However, automatic examining process of production quality is still dropout, and present situation of examination has to rely on skilled worker. On the examining process of mini-motor for the automobile, the examination is performed using electric current wave-form, sound, vibration, etc. [1] [2] [3], which are measured by human vision, touch, sense of hearing, under noload condition. The standard judgement cannot describe quantitatively and clearly. It seems to be influenced by skilled worker's experience perception or condition. Therefore, it is desirable to offer the standard examining process and auto diagnostic system, by which the production of inferior works is suppressed and judgement method of reliability and with high-grade positive answer is supported [7] [8]. On this research, we have used the manufacturing company's mini-motor, analyzed the rotating sound into computer digital data and developed the standard examining process and verified the algorithm of judgement. We also applied noncommittal criterion with fuzzy system, and verified the possibility of automatic diagnosis.

2. Mini-motor Acoustic Signatures

In mini-motor, the components investigate in this paper. Fig.1 shows out ward and main dimension. The mini-motor was construction assembly by stator, armature and end bracket.



① Air Pipe
② Toothed Wheel
③ Worrm Gear and Worm Wheel
④ Stator
⑤ Enternally Magnet
⑥ Armature
⑦ Ball Berings
⑧ End Bracker

Fig. 1 Outward and main dimension of mini-motor

The data use in this project were collected with microphone in bench tests conducted by Electricity de France. The test voltage of mini-motor is 13.5V. The load of torque is 2.6kgf.m. The time dependent data were transformed using FFT techniques into low-frequency (10 ~ 1000 Hz) and high-frequency (10 ~ 12 KHz) spectra. Data are collected using an microphone placed in the radial direction to the loading of the mini-motor. The microphone is establish near by the End Bracket about 300mm in turn is stuck to the rolling element. From these measurement, spectra are generated using FFT techniques. Spectra are averaged over 8 samples with a HANNING window [4]. The spectra have 1,024 points. The acoustic voltage is -10V ~ +10V and sampling intervals of 0.04ms.

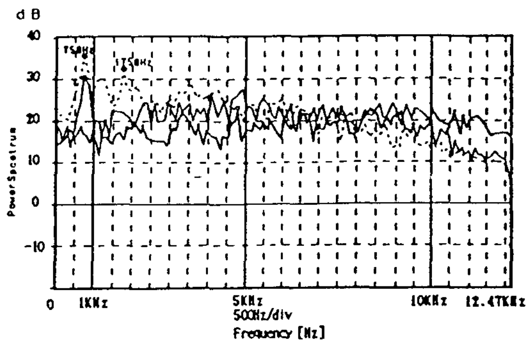
We got the judgement of 92 motors from manufacturing company. They were rotated in forward direction and backwards direction, and we picked up the total of 184 acoustic signals. Acoustic description are also calculated that describe overall acoustic levels in the various components. The technique described here is based on the information contained in these descriptor and the spectra.

Generally, each machine defects produces a set of acoustic components that allows for recognition of different faults. For mini-motor, there are formulas for calculating the frequency regions in which features may appear in the spectra. For example, in identifies the frequency at which defects of the inner race would appear and there are similar formulas for faults of the outer race and rolling element.

Noise frequency = NZ / 60

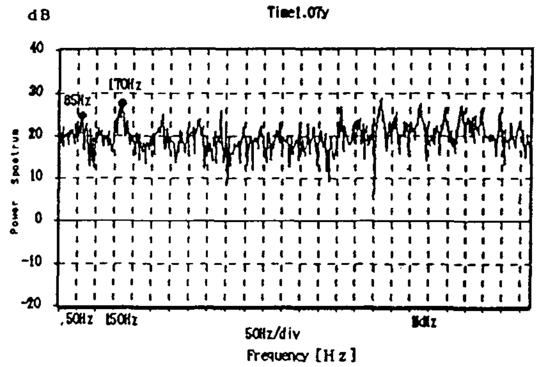
N : Integral number Z : Number of gear

The specification of mini-motor acoustic signal is shown in Fig.2. Low speed mini-motor of effective in the range of 0 to 1KHz is extremely high, cause as electromagnetism niose.



Fine line : Failure motor A frequency model
Dotted line : Failure motor B frequency model
Thick line : Good motor frequency model

Fig. 2



Low-frequency spectra

Fig. 3

15 times at the basic of electricity wave as 750Hz also occurred electromagnetism noise. Range of 1 KHz to 5 KHz frequency spectra is high because of resonance noise. Power spectra of defect motor is higher rather than good motor. Range of 5KHz to 10 KHz frequency spectra as stability area also range of 10KHz to 12.47 KHz is good and failure characteristic area and high power spectrum is assume as failure motor. Fig.3 is enlarge from low-frequency spectra. It show the mini-motor bearing occurred the signal by 50 times as 85Hz and 100 times as 170 KHz peak level rate.

3. Parameter Estimation

In order to process data using fuzzy logic, the input data must be scaled to the operating range of algorithms. For this project, we adoption 4 spectra values of discred time signals and 3 spectrum of frequency band as characteristic parameter.

1) Average x of total absolute value $\sum x = \sum_{i=1}^{N} |x_i|$

$$\overline{x} = \frac{\sum x}{N}$$

2) Skewness α of standard deviation $\delta = \frac{\sqrt{\sum_{i=1}^{N} (|x_i| - x)^2}}{N-1}$

$$\alpha = \frac{1}{\delta^3} \cdot \frac{\sqrt{\sum_{i=1}^{N} (|x_i| - x)^3}}{N-1}$$

3) Kurtosis

$$\beta = \frac{1}{\delta^4} \cdot \frac{\sqrt{\sum_{i=1}^{N} (|x_i| - x)^4}}{N-1}$$

4) Crest Factor

$$Cf = X_{max} / X_{RMS}$$

5) Total range of low-frequency spectra

$LP = \sum_{i=1}^{N}$ (0 ~ 1 Khz)

6) Total range of high-frequency spectra

$HP = \sum_{i=1}^{N}$ (10K ~ 12.47 KHz)

7) 15 times frequency spectra based on electricity sources wave.
For fuzzy logic, the various values for each pattern are calculated and spectra scaled to the appropriate range.

4. Fuzzy Methodology

In this paper, several problem concerning with quality will take as probability set, indicate as condition vector. And this vector detention function μ_y (Yi) as

Y = {y1, y2, y3, ...yn}

n dimension as defect clarify.

As several cause of defect occurred deal as each characteristic set. The characteristic vector belonging to detraction function of μ_x(Xi) as

X = {x1, x2,x3,.........xm}

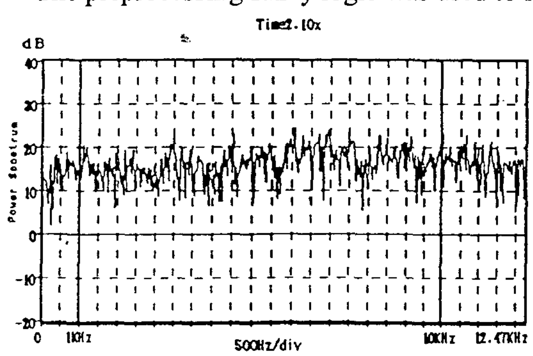
m dimension as a variety of characteristic.

Generally, the judgement will decide by 2 rate of region [0,1] as detention function Xi, as good ... d failure. However, all kinds of mini-motor's characteristic Xi and quant' are not relation c'early in ratio. Must of existence quantity will not indicate clearly. Example stator resonance part processing not order occurred metal noise. The situation of μ_A difficult to express destination in two rate logic.

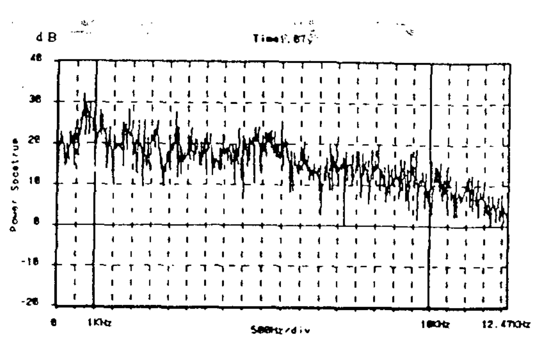
Then based on fuzzy logic concept, the existence ambiqlious height can accuracy and exactly detonate in variety value logic. The height of a fuzzy net A evaluates the possibility of finding X at least one element which fits the predicate A exactly. A is normalized when such an element can be exhibited. Owing to cause interpretation of the equation A ○ R = B, where R is fuzzy relation. A is fuzzy set of symptoms as shown as above. B is a fuzzy disease. R represents the membership function and is estimated from a set of patients on whom symptoms are observed and who are diagnosed by reliable physicians. For good effective to estimate the defect we provide a new probability concept of fuzzy to analysis the failure [5]. The fuzzy functioning projection is to complementary the problem.

5. Results

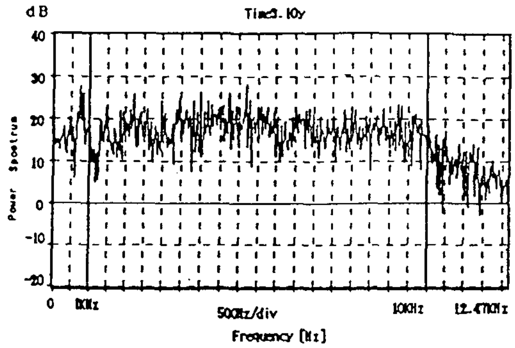
The preprocessing fuzzy logic was used to identify possibility faulty system. The input to



Good motor frequency model
Fig. 4

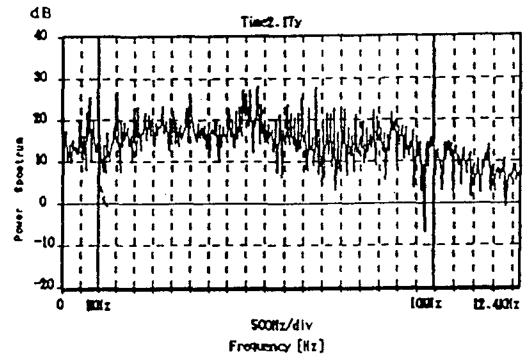


Failure motor frequency model
Fig. 5



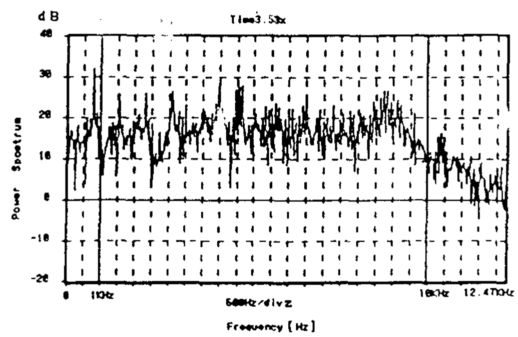
Usual system detection error frequency model

Fig. 6



Usual system detection error for metal noise frequency mode

Fig. 7



Metal noise frequency mode

Fig. 8

the system were the normalized values of the high-frequency descriptor, low-frequency descriptor, time signal descriptor and corresponding differences of these descriptor between parameter. The differences provide information about sudden increases in the descriptors (rate) and are essential in the detection of certain faults. The output of fuzzy system indicate absence of a fault and one indicate a possibly faulty signature. For total of patterr of failure the system can estimate and diagnostic the defect accuracy.

Number	A	B	C	D	E	Defect {0,1}
210 x	0.35	0.35	0.35	0.35	0.35	0.35
217 y	0.50	0.65	0.45	0.75	0.60	0.75
310 y	0.64	0.65	0.64	0.74	0.60	0.74
353 x	0.86	0.71	0.65	0.75	0.65	0.86
107 y	0.55	0.90	0.85	0.90	0.85	0.96

A : Main body defect, cause of impact element
B : Part processing not order occurred metal noise
C : Armature abnormal defect signal noise
D : Cycling occurred electromagnetism noise
E : Resonance noise

6. Conclusions

We are working on the implementation of meteorology for interpreting acoustic measurements based on fuzzy theory. The anticipated advantage of developing such system is the possibility of automating and diagnostic process for mini-motor and low speed mini-motor diagnostic systems that complement traditional signal analysis by dealing with the nonlinear characteristic of the signal. The flexibility of using fuzzy theory for spectra data has been establish. Under this study, we have achieved 92% accuracy while maintaining the diagnostic range 82% of the original system.This system also can point out the possibility of defects.

Using the low-frequency and high-frequency spectra adds to the robustness of our system because we able to detect incipient faults a well as severe defects. In addition, the information provided by expert may be used to fuzzy theory and possibly faulty signatures. We feel that fuzzy theory can provide a meteorology for improving the analysis of spectra for acoustic signal analysis and may provide a system to estimate and diagnostic of mini-motor.

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